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Job satisfaction: An explorative study on work characteristics changes of employees in Intralogistics 4.0

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Abstract

The increasing trend toward digitalization in logistics poses a significant managerial challenge, particularly by fundamentally changing the traditional, manual workplaces in intralogistics. Although intralogistics processes have, in some cases, already been automated or are supported by smart technologies, humans remain an inevitable part of future intralogistics but with changing work characteristics. This study aims to examine the influences of the transition toward Intralogistics 4.0 on work characteristics of intralogistics employees. First, a systematic literature review on work characteristics and job satisfaction in a broader Logistics 4.0 context was conducted. Thereafter, a qualitative, explorative methodology was employed to examine the perception of work characteristics that impact job outcomes such as job satisfaction, motivation, and performance at different Intralogistics 4.0 maturity levels. The results of semi-structured interviews conducted across seven companies demonstrated the significant, heterogeneous changes of work characteristics related to the type of technology applied in Intralogistics 4.0. Our findings indicate that the development toward Intralogistics 4.0-implemented workplaces does not have a simple or predefined impact on humans; instead, the individual design is relevant and can improve the workplaces with more opportunities for satisfying and motivating jobs.

KEYWORDS

Industry 4.0, Intralogistics 4.0, Intralogistics 4.0 maturity, Job characteristics, Job satisfaction, Logistics 4.0, Qualitative interview, Systematic literature review

INTRODUCTION

The digital transformation that involves the utilization of digital technologies in all spheres of life has a great influence on the society and the economy as a whole (Holmström et al. 2019; Kagermann et al. 2013; Reis et al. 2018). This trend presents new challenges to organizations for satisfying the changing and individualized customer demands. Specifically, logistics companies perceive this digital transformation as a main driver of future business success, and logistics also codetermines the outcome of this digital transformation in industry and trade because the efficiency and quality of logistics affect customer satisfaction and overall company performance (Cichosz et al. 2020; Davis-Sramek et al. 2008; Springinklee & Wallenburg, 2012). In this context, the World Economic

Forum estimates that the digital transformation has a value at stake in the logistics sector of US$ 1.5 trillion by 2025 (World Economic Forum, 2016). Despite this evident potential, a recent survey has shown that 79% of the participants classified the digital transformation in logistics as a major challenge (Rohleder, 2019). Logistics companies themselves are significantly influenced by this digital transformation through incorporation of new technologies such as Big Data, artificial intelligence (AI), and cyber-physical systems (CPSs) also in intralogistics processes (Cichosz et al. 2020; Hofmann & Rüsch, 2017).

The share of manual work is still high in intralogistics as internal transportation, packaging, or order picking have traditionally been performed manually (Michel, 2016; Michel, 2019). In the United States, for example, more than 1.4 million employees worked in the storage and warehousing sector in March 2021, with 1.26 million of these as production and non-supervisory employees (U.S. Bureau of Labor Statistics, 2021). Major changes are expected in intralogistics owing to the multitude of possibilities for supporting or automating these tasks (Winkelhaus & Grosse, 2020). In particular, intralogistics (and here especially warehousing) is currently seen as the area of logistics that may benefit the most from digitalization and automation (Rohleder, 2019). Besides automation technologies that enable physical tasks to be performed without human involvement (Fasth-Berglund & Stahre, 2013), digital technologies, that encompass both tangible equipment such as computers and mobile devices as well as intangible goods such as software and the Internet (Ibem & Laryea, 2014), further improve the capabilities of automation technologies: "Like automation, the goal of system autonomy is to achieve tasks with little or no human intervention [...] Whereas previous generations of automation have typically employed logic-based programming, today's system autonomy efforts are leveraging computational intelligence and learning algorithms to better adapt to unanticipated and changing situations" (Endsley, 2017). This technological trend is part of *Logistics 4.0*, with Intralogistics 4.0 as a subdomain of this concept that this paper aims to investigate (Madsen, 2019; Winkelhaus & Grosse, 2020).

Although business processes can change significantly in this development, numerous researchers have concluded that human workers will remain an integral part of future logistics workplaces (Erol et al. 2016; Kadir et al. 2019; Kagermann et al. 2013). Therefore, human workers constitute an inevitable part in this progress with significant influence on the outcomes of logistics systems (Kagermann et al. 2013).

Changing intralogistics work transforms work characteristics as well, which affects the employees' perceptions of their workplaces. As work characteristics influence job satisfaction (Morris & Venkatesh, 2010), job satisfaction changes in Intralogistics 4.0, with possible consequences for individual work outcomes such as turnover intention, motivation, performance, and organizational commitment (Ang & Slaughter, 2001; Autry & Daugherty, 2003; Loher et al. 1985; Morris & Venkatesh, 2010). In addition, job satisfaction can be considered as a value in itself as it also contributes to the concept of social sustainability (Brockhaus et al. 2013), which is widely discussed in a broader logistics context (Carter & Washispack, 2018; Castillo et al. 2018; Grosse et al. 2015; Klumpp & Zijm, 2019).

However, little is known about the impact of Intralogistics 4.0 on manual workplaces in this field despite its economic importance, the high share of manual human work, and the expected effects of Intralogistics 4.0 on human work in this sector. Earlier research noted that the changing roles of workers often remain inexplicably unaddressed in the entire Industry 4.0 domain (Kadir et al. 2019; Winkelhaus & Grosse, 2020), and only first conceptual studies highlight the need for examination and make initial contributions (Cimini et al. 2020; Neumann et al. 2021). Therefore, this study investigates the relationship between the developments of Intralogistics 4.0 and the characteristics of intralogistics workplaces. The Intralogistics 4.0 maturity is an important tool for benchmarking and comparing different expressions of this development, that is, the kind and depth of technology usage. Against this background, our study aims to answer the following research questions (*RQs*):

RQ 1: How do work characteristics of intralogistics employees change with different Intralogistics 4.0 maturity levels?
RQ 2: What are the effects of digital technologies as compared to automation technologies on work characteristics of different Intralogistics 4.0 maturity levels and what are the driving and inhibiting mechanisms behind this?
RQ 3: How does the Intralogistics 4.0 maturity level impact job satisfaction in intralogistics?
RQ 4: How can practitioners anticipate the development toward Intralogistics 4.0 in designing future intralogistics workplaces?

To answer these *RQs*, two methods are applied: A systematic literature review is performed (part 1) with the aim of understanding the state of knowledge, verifying the research gap and deducing theoretical insights. The results of part 1 are reflected in light of a qualitative, explorative study applying semi-structured interviews to compare work characteristics of workplaces with different levels of Intralogistics 4.0 maturity (part 2).

Applying this qualitative approach has three main reasons. First, Intralogistics 4.0 is an emerging phenomenon facilitated through the digital transformation, and its vital impacts on work characteristics are still underexplored (Korner et al. 2019). A qualitative method facilitates to inductively expand, transfer, and verify existing hypotheses and concepts (Fawcett et al. 2014; Gioia et al. 2012; Stank et al. 2017). Second, the current study considers a complex interaction within this emerging phenomenon and attempts to comprehend these relationships (Fawcett et al. 2014), such as the impacts of technology usage on the work characteristics. Third, this study aims to understand the worker's perspective without predetermination (Grosse et al. 2016), or on a theoretical level as in previous studies. Thus, a qualitative method is appropriate to answer the *RQs*. In this view, this work contributes toward the development of a middle-range-theory.

The remainder of the article is structured as follows: The subsequent section provides the theoretical foundations of the study followed by a review of the relevant literature. Thereafter, the research methodology used for data collection and evaluation is detailed. Then, the results of the data assessment are presented to answer *RQ* 1. Subsequently, the obtained data are synthesized to answer *RQs* 2 and 3 by analyzing the impacts of technology provision and usage on work characteristics and respective mechanisms behind these impacts. The results are discussed from a managerial perspective, making them applicable for the design of future workplaces for answering *RQ* 4. The last section summarizes the study, presents an outlook on future research, and discusses its limitations.

FOUNDATIONS OF THE STUDY

Work characteristics and job satisfaction in general

Job satisfaction has a cognitive and an affective aspect (Fisher, 2010) and can be described analogously to an early definition of Locke (1976) as a positive emotional state resulting from the appraisal of one's job experiences (Tietjen & Myers, 1998; Yousef, 2016). Various models have attempted to explain the relation between job design and job satisfaction (Fisher, 2010) differentiating between an individual, a group, and an organizational level. The "Job Characteristics Model" (Hackman & Oldham, 1975) hypothesizes a relation between job characteristics and personal and work outcomes such as job satisfaction (Hackman & Oldham, 1975) and has frequently been studied in the literature (see the reviews of Boonzaier et al. (2001) or Loher et al. (1985)). We therefore evaluated it as particularly relevant for this study. The job diagnostic survey, developed by Hackman and Oldham (1974) based on their "Job Characteristics Model", includes five main characteristics of the job: (1) skill variety, (2) task significance, (3) task identity, (4) autonomy, and (5) feedback. These characteristics contribute to critical psychological states, with "experienced meaningfulness of work", "experienced responsibility for outcomes of the work", and "knowledge of the actual results of the work", impacting job satisfaction. Several studies adopted the job diagnostic survey for further analysis, for example, to evaluate moderating effects of IT implementation on the relation between job characteristics and job satisfaction (Morris & Venkatesh, 2010).

Theoretically expanding the research of Hackman and Oldham (1975), Morgeson and Humphrey (2006) created a more comprehensive survey, referred to as the "Work Design Questionnaire" (WDQ), that facilitates the assessment of the work characteristics that contribute to job satisfaction. The authors referred to the terms "work characteristics" and "work design" in contrast to "job characteristics" and "job design", because "work" focuses on a broader context of the job and its environment (Morgeson & Humphrey, 2006). In the following, we use the broader term "work characteristics", although the term "job characteristics" is used more frequently in the literature. The category "task characteristics" included in their survey is similar to the characteristics developed by Hackman and Oldham (1975). Apart from this, Morgeson and Humphrey (2006) included additional categories in the WDQ: "knowledge characteristics", "social characteristics", and "contextual characteristics" (Morgeson & Humphrey, 2006). The category system developed by Morgeson and Humphrey (2006) is shown in Figure 1 and has a strong relation to job satisfaction and related concepts of intrinsic motivation. Thus, the WDQ enables a comprehensive analysis of job satisfaction in the digital transformation. The proposed system is used as a starting point for developing qualitative interview questions in this study because we do not question the general relationship between work characteristics and job satisfaction; instead, the aim of the current study was to provide answers on how the qualitative *how* and *why* of the transformations impact job satisfaction, and not the quantitative *how many* (Fawcett et al. 2014; Stank et al. 2017). The questionnaire was replaced with an open form of interview questions to answer the *RQs*; the method is outlined in more detail in the methodology section.

Work characteristics and job satisfaction in logistics

Despite the high relevance of work characteristics for job satisfaction, performance, turnover intentions, and

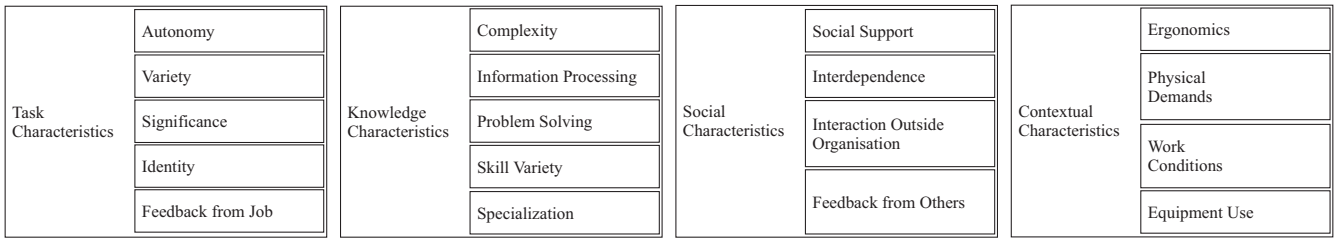

FIGURE 1 Work characteristics that may influence job satisfaction

several other job outcomes, only a few works addressed this topic in a logistics context. Maloni et al. (2017) found that most related studies primarily focused on specific professions such as truck drivers or warehouse employees (Min, 2007) or measured job satisfaction without determining the driving factors and inhibitors (Maloni et al. 2017). Nonetheless, some studies determined the impacts of certain work characteristics including contextual factors, such as job security and pay, on the workers' perceptions of logistics and supply chain workplaces. These studies reported that certain organizational concepts such as lean production (de Haan et al. 2012) and the workforce level (Maloni et al. 2017) play key roles in the job satisfaction of logistics employees. Moreover, supervisors can contribute toward job satisfaction by providing coaching (Ellinger et al. 2005) or by influencing possible work–family conflicts in logistics (Maloni et al. 2019). Furthermore, employer-sponsored training can positively impact workforce productivity and job satisfaction in logistics (Chhetri et al. 2018).

In summary, most studies either did not examine the driving factors of job satisfaction, or they focused only on a few aspects such as autonomy or task identity (de Haan et al. 2012) or context factors like payment (Min, 2007). In addition, the identified studies did not focus on the application and impact of technologies on work characteristics and job satisfaction and are therefore not suitable to provide a broad theoretical basis for this work. Hence, a detailed investigation of these impacts is necessary because the continuing digital transformation of the logistics sector questions current knowledge and understanding.

Logistics 4.0 and Intralogistics 4.0 maturity

The concept of Logistics 4.0 originates from Industry 4.0, which was initially coined as an overarching term for several developments in the context of the digital transformation in the industrial sector (Kagermann et al. 2013). Industry 4.0 incorporates a paradigmatic aspect that considers the changes toward individualized products, globalization, and shortening product life cycles, and a technological aspect that considers the incorporation of CPSs, Big Data, or AI (Hofmann & Rüsch, 2017; Lasi et al. 2014).

Both aspects also influence the logistics and intralogistics sphere (Min et al. 2019) through, for example, the implementation of smart goods (Holmqvist & Stefansson, 2006), the application of AI for planning and advanced robotics (Klumpp, 2018), or the realization of mass customization (Christopher & Ryals, 2014). Logistics 4.0 can be defined as "the logistical system that enables the sustainable satisfaction of individualized customer demands without an increase in costs and supports this development in industry and trade using digital technologies" (Winkelhaus & Grosse, 2020). We refer to Intralogistics 4.0 as being all parts of Logistics 4.0 that are concerned with intralogistics processes.

Based on the distinction between automation technologies that can replace physical tasks and digital technologies that can replace cognitive tasks (Endsley, 2017), we differentiate between four effects of Intralogistics 4.0 technologies (see Figure 2): (1) Digital technologies can substitute cognitive tasks such as administration; this can be termed cognitive automation (Choe et al. 2015). Warehouse management systems and AI are examples for this kind of technologies that ease or automate cognitive tasks. (2) Automation technologies allow the substitution of physical tasks such as order picking, transportation, or material handling with the help of CPSs, AGVs, or collaborative robots. (3) Digital technologies and automation technologies further improve one another. First, digital technologies enable the progression of automation technologies to autonomous technologies (Endsley, 2017). Second, sensor-based systems successively generate data for further improvement of digital technologies. Thus, these more advanced automation technologies can automate further physical tasks. (4) Digital and automation technologies can also support human operators in different ways. As digital technologies cannot perform physical tasks, they can support human operators in performing these tasks, for example, by guiding the operator or giving feedback on task performance. In contrast, automation technologies cannot perform cognitive tasks of operators, but support these, for example, by only presenting one

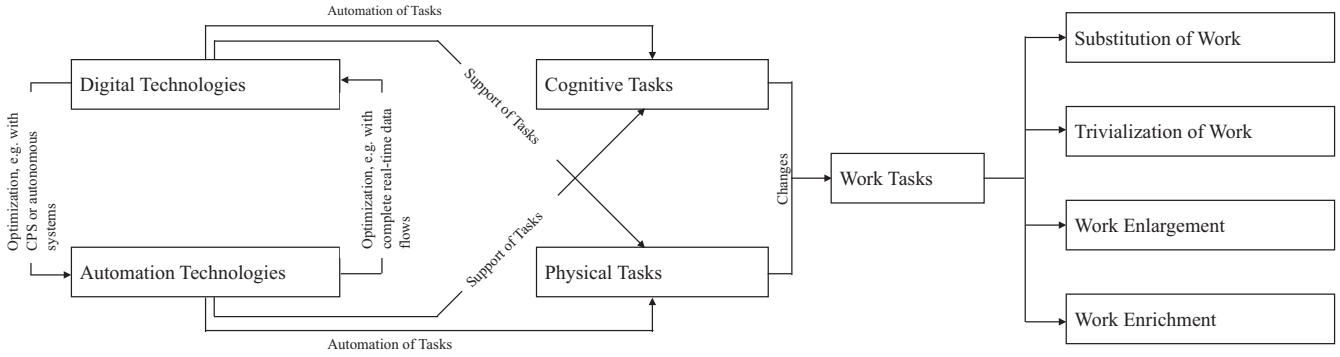

FIGURE 2 Interactions between digital and automation technologies possibly influencing work tasks

product at a time in front of a machine, which trivializes (cognitive) searching and identifying tasks.

Both digital and automation technologies are an integral part of Intralogistics 4.0, which can have four effects on work tasks: (1) complete substitution of tasks, (2) trivialization of tasks that are not automatable owing to the replacement of prior manual tasks by advanced systems (Waschull et al. 2019), (3) enlargement of tasks, where the share of repetitive (automatable) tasks is reduced and additional, more diverse tasks are added to the work, and (4) enrichment of tasks with the requirement of qualified employees for more difficult tasks (Waschull et al. 2019). However, as the importance of humans in this industrial development has already been emphasized in the seminal report on Industry 4.0 by Kagermann et al. (2013) and research on the *Operator 4.0*, a complete substitution of workers by machines is not expected in most areas (see, e.g. Cimini et al. 2020; Guérin et al. 2019; Ruppert et al. 2018).

As Intralogistics 4.0 can be driven by diverse technologies, we use a maturity model to evaluate and compare different levels of technology usage en route to Intralogistics 4.0 in part 2 of this article. Maturity models are suitable as they can provide a basis for benchmarking and as-is assessments (Asdecker & Felch, 2018; Krowas & Riedel, 2019). In a maturity model, the degree to which a certain target state is achieved is expressed by consecutive maturity levels (Krowas & Riedel, 2019).

To select a suitable maturity model for the study at hand, a systematic literature review was conducted. Using the search string ("*Industry 4.0*" *maturity model*) in the title, abstract, and list of keywords in the Web of Science database, 49 journal articles and proceeding papers were identified. We evaluated these papers for a detailed development and discussion of a maturity model that was suitable for our research and thus reduced the set of relevant papers to 22. In a second refinement step, we limited our review to articles focusing on logistics or supply chains, leading to three articles of relevance: Leyh et al. (2017), Asdecker and Felch (2018), and Sternad et al. (2018).

The model of Asdecker and Felch (2018) is of major importance for the assessment of the Intralogistics 4.0 maturity, as it includes a detailed description of the different maturity levels and focuses on technology-improved processes instead of, for example, management and culture issues (Krowas & Riedel, 2019). We further identified a maturity model for Intralogistics 4.0 (Krowas & Riedel, 2019) that can be applied to extend the model of Asdecker and Felch (2018), even though no full documentation is available.

Overall, five development stages were identified that consider characteristics from Level 1 for companies or workplaces that are not Intralogistics 4.0 mature up to Level 5 for highest Intralogistics 4.0 maturity of companies or workplaces. For the study at hand, it is important that both digital and automation technologies are considered relevant as these are integral parts of CPSs as a core technology of Industry 4.0 and (Intra-)Logistics 4.0. For example, the levels of automation identified range from manual, mechanically supported, mechanized, and automated to autonomous processes (Krowas & Riedel, 2019). Relevant process steps include internal transportation, storing, and order picking.

Before the qualitative study is performed, part 1 that grounds on a systematic evaluation of the literature is addressed to support the validity of the subsequent empirical evaluation.

LITERATURE REVIEW ON WORK CHARACTERISTICS AND JOB SATISFACTION IN INDUSTRY 4.0 AND LOGISTICS 4.0

Following Munn et al. (2018), we decided to perform a systematic literature review and not a scoping review as "scoping reviews do not aim to produce a critically appraised and synthesized result." We performed the review for three reasons:

1. To assess the state of knowledge in our study's research field and point out the research gap in detail.
2. To support the preparation of the interviews in the intersection of technologies, work characteristics and job satisfaction (albeit in different contexts).
3. To interpret and reflect the results from the qualitative study in light of the review.

The transparent and reproducible method of sample derivation (Fink, 2005) enables us to identify publication patterns and gaps in existing research (Seuring & Gold, 2012; Tranfield et al. 2003). The systematic literature review also considers insights from research on IT systems to examine the development path of the digital transformation, which is strongly related to the emerging Intralogistics 4.0 systems.

Review methodology

The literature sample was generated in five steps following the suggestions of Krippendorff (2013) and Carter and Washispack (2018):

1. The search string considered two keyword groups shown in Table 1. Group A includes terms related to work characteristics as keywords, whereas Group B comprises terms generally related to the digital transformation to additionally cover possibly relevant studies from sectors where the term Industry 4.0 is not commonly used. We did not use keywords related to "logistics" as this may narrow the search with risks of missing important references. Each article should contain at least one keyword from both groups. The keywords were searched across all fields in the database "Web of Science Core Collection," which was chosen because this database contains a comprehensive amount of multidisciplinary, high-quality journals. The keyword search yielded an initial sample consisting of 364 studies.

TABLE 1 Keywords used in the database search

Group A	Group B
Job Characteristic	Digital Transformation
Work Characteristic	Industry 4.0
Job Satisfaction	Logistics 4.0
	Automation
	Information System
	Information Technology
	Human–Machine

2. The sample was refined using the exclusion/inclusion (E/I) criteria shown in Table 2 that were structurally adapted from Liao et al. (2017). In the first refinement step, we selected only peer-reviewed English journal articles to guarantee a high scientific standard of the publications. 313 of the initial search results remained post refining.
3. The title, abstract, and keywords were read and analyzed for relevance by two coders. In case of unclear classifications, the articles were discussed to reach consensus. This process did, however, not result in significant deviations from the initial assessment. Articles remained in the sample in case no clear decision could be derived from the information to ensure that no relevant article was excluded. 39 articles remained in the sample at the end of this process step.
4. The articles were read completely, and those not focusing on the selected primary topics (e.g., work characteristics) were excluded from the sample. The literature sample consisted of 22 articles at the end of this step.
5. A backward snowball search conducted on the references resulted in two additional articles, leading to a final sample size of 24. The analysis results of the sample are described briefly to examine the state of knowledge, highlight the research gap, and allow the transfer of knowledge from associated research.

Results of the review

The results of the review are summarized in the Appendix 1. Three types of models were identified in the literature sample: (1) Technology Acceptance Models, (2) Job-Demands-Resource/Job-Demands Job-Control Models, and (3) Job Characteristics Models. Most studies focused on the implementation phases of IT systems instead of stabilized conditions. Digital technologies such as the Internet and IT systems, automation technologies, and CPSs that can be viewed as integrations of digital and automation technologies (Lee, 2008) impact work characteristics relevant for job satisfaction. The findings of the review thus point toward possible impacts and mechanisms that are relevant for work characteristics changes (e.g., perceived complexity) also in intralogistics. In addition, the review also hints at conceptual differences between the effects of automation and digitalization on work characteristics. Key takeaways from the literature analysis relevant for the study at hand can be summarized as follows:

- Automation leads to deskilling of shopfloor employees (de Witte & Steijn, 2000).

TABLE 2 Inclusion and exclusion criteria of the systematic review

E/I	Criteria	Criteria Explanation
Exclusion	Search engine reason	The article is not written in English, or it was not published in a peer-reviewed journal
	Non-related	The article is not an academic article (e.g., editorials or newspapers)
		The keywords are related to another topic due to homonyms
	Loosely related	The keywords only appear in the references
		The article generally concerns the topic of relevance but in a sector or domain that is structurally different, such as public sectors or marketing
		The article uses keywords of a category only in a quotation, example, or in the research outlook/future directions without investigating it
Inclusion	Partially related	The article concerns the intersection of categories at least in a part/section of the article
		The article addresses the topic without using the keywords but synonyms
	Closely related	The article concerns keywords of both categories in depth and majorly focuses on the topic of interest

- During IT system implementation, perceived process complexity and rigidity increase, and autonomy, skill variety, and feedback are moderated by the implementation.
- Conceptually, digitalization and especially automation are expected to increase task complexity, which increases knowledge needs and skill variety and reduces the autonomy for low- and medium-skilled jobs.

Although organizational aspects are considered in various publications, these studies mostly focus on the implementation phase and are thus not addressed in the research at hand, which instead focuses on stabilized systems.

The results of the literature review also reveal four gaps in the existing literature:

1. Only a few studies examined the influences of digitalization on work characteristics in a broader context. Most studies focused on the implementation phase and only on one specific technology, in most cases a comprehensive IT system like an ERP system.
2. Most studies did not focus on shopfloor workers who might operate with less complex IT systems.
3. The intersection between automation technologies and digital technologies was not considered in depth in the literature, although effects of physical automation and cognitive automation are probably relevant.
4. The literature did not focus on intralogistics, and only a few papers explored the logistics sector. The study of Bala (2013) is the only research identified in the sample that addressed the logistics sector and investigated the effects of technology usage (in this case: the implementation of a supply chain management IT system) on work characteristics and job satisfaction.

Overall, there is a clear research gap on how the digital transformation impacts work characteristics and, subsequently, job satisfaction in intralogistics.

RESEARCH DESIGN AND METHODOLOGY

A qualitative approach was chosen to explore the *RQs* as outlined in the introduction. Binder and Edwards (2010) argued that qualitative methods are still infrequently applied in operations management, for example, compared to social sciences. We follow the argumentation of Gioia et al. (2012), who stated that examining new or questioning existing constructs "requires an approach that captures concepts relevant to the human organizational experience in terms that are adequate at the level of meaning of the people living that experience and adequate at the level of scientific theorizing about that experience."

Data collection process

The literature discusses a broad portfolio of qualitative research methods for generating data, such as observations or structured interviews (Phellas et al. 2011). Semi-structured interviewing was considered suitable for the current study as it allows an analysis of perceived causal relations, helps gaining insights into the perceived reality, and facilitates the assessment of an interviewee's perception (Venkatesh et al. 2010). In addition, interviewees and interviewers have more freedom to focus on aspects of relevance and previously unknown situations, as compared

to structured interviews. Therefore, semi-structured interviews are suitable for analyzing emerging phenomena. This study followed four major steps in conducting the semi-structured interviews at the companies with a cross-organizational approach.

1. The cases and interview partners were selected from intralogistics workers as the focal group for the investigation. The research principle of "maximum heterogeneity" was followed for case selection, such that the cases varied in relevant key dimensions (such as work environments, industrial sector, and Intralogistics 4.0 maturity) as much as possible (Suri, 2011). Interviewees have worked for the company for at least one year so they have the necessary knowledge regarding the work. A description of the interview cases is presented in Table 3. The interviewees worked in warehouses, but also in pre- and post-processing steps, for example, receiving and truck-loading. The sample contains companies from five different sectors and varies from completely manual intralogistics processes to highly technology-supported processes. All cases included in the study were placed in Germany to control for location-based effects (Anand et al. 2007).
2. Second, an interview guide was prepared following the suggestions of Grosse et al. (2016). The interview guide was split into four sections as shown in Table 4.
3. Third, the interviews were conducted by the same researcher to avoid bias and were based on the suggestions of Grosse et al. (2016). The interviews took place between March and September 2019, where each interview was audio recorded in agreement with the managing directors, interviewees, and the workers' councils following data privacy guidelines. Each interview required 20–30 min. No major issues could be observed during the interviews, for instance, concerning understandability of the questions or meaning of the technical terms. Overall, 16 interviews were conducted, and 132 pages of transcripts were analyzed.
4. The fourth step included the preparation of the analysis with the transcription of interview recordings. We followed the recommendations of Mayring (2014) and Gioia et al. (2012) during coding and data analysis to ensure reliability and validity. The method of Gioia et al. (2012) suggests to derive first-order categories that are mainly informant-centric and second-order categories that are obtained based on the former as researcher-centric ones. The approach is more descriptive in its aim (Sodero et al. 2019) and enables us to systematically describe the relations between Intralogistics 4.0 and work characteristics. This method is adequate for the study at hand, as it mediates between the experiences of knowledgeable agents (the interviewees) and the researchers' constructs (Gioia et al. 2012; Sodero et al. 2019). Based

TABLE 3 Description of cases

Case	Position of interviewee	Industry	Company Size[a]
Case 1.1	Order Picking	Wholesale	Medium
Case 1.2	Order Picking	Wholesale	Medium
Case 2.1	Order Processing	Production	Medium - Large
Case 2.2	Receiving	Production	Medium - Large
Case 3.1	Order Picking	Production & Trade	Medium
Case 3.2	Order Picking	Production & Trade	Medium
Case 4.1	Storekeeping	Publisher	Small
Case 4.2	Receiving	Publisher	Small
Case 5.1	Storekeeping	Food	Large
Case 5.2	Order Picking	Food	Large
Case 6.1	Order Picking	Manufacturing	Medium
Case 6.2	Storekeeping	Manufacturing	Medium
Case 6.3	Packing	Manufacturing	Medium
Case 7.1	Loading/Storekeeping	Food	Large
Case 7.2	Loading/Storekeeping	Food	Large
Case 7.3	Storekeeping/Disposition	Food	Large

[a]Estimated company size in respect of the EU definition (2003/361/EG) on small and medium-sized enterprises (small companies: <50 employees, <10 million Euro annual turnover; medium-sized companies: <250 employees, <50 million Euro annual turnover; above this, it is a large company).

TABLE 4 Interview guide

	Section 1	Section 2	Section 3	Section 4
Focus	Basic Information	Core Questions	Expectations	Open Questions
Content	Job title, work history, typical work process	Open questions related to all Work Characteristics named in the WDQ	Expectations regarding more Intralogistics 4.0 mature workplaces	Any topics that were not addressed yet
Example	Could you please tell me about the typical work processes you perform every day?	Could you please tell me about the physical load you have to handle during your work?	What developments do you expect for your workplace regarding the digital transformation?	Is there anything we did not yet talk about you would like to add?
Sources	Grosse et al. (2016)	Grosse et al. (2016), Hackman and Oldham (1975), Morgeson and Humphrey (2006), Stegmann et al. (2010)		Grosse et al. (2016)

on this methodology, the current study applied a data analysis and interpretation that followed the five steps shown in Figure 3. First, the transcripts were coded, and the first-order categories were derived. Thereafter, these categories were consolidated and abstracted to form second-order categories. Until this step, the analysis focused on workplaces of a comparable type that is based on the estimated Intralogistics 4.0 maturity level and its technological driver that will be described subsequently in more detail. Based on these second-order categories of different workplace types and with different levels of Intralogistics 4.0 maturity, the impacts of the Intralogistics 4.0 maturity on the work characteristics were analyzed for every workplace characteristic. Based on this, the conclusions were derived to understand the impacts of Intralogistics 4.0 on job satisfaction.

The analysis described above was verified for intercoder reliability. Therefore, the interviews were coded by two coders and the coding results were assessed for consistency. Minor differences were identified during the comparison but could be solved through discussions among the coders.

Intralogistics 4.0 maturity of the cases

The Intralogistics 4.0 maturity of the case workplaces was estimated according to the described maturity models of Asdecker and Felch (2018) and Krowas and Riedel (2019) grounding on the interviews. The flow of information and the digital and automation technologies used were taken into consideration. Four cases were identified to fit to the lowest Level 1, five to Level 2, five to Level 3, and two to Level 4. Given that the application of advanced digital and automation technologies in intralogistics is limited (see, e.g., Napolitano (2012) or Michel (2016)), examples for Level 5 intralogistics activities are still scarce and our results are thus plausible. In contrast to this, Level 1 processes are still common in intralogistics and it might be questioned whether this mostly analogue and manual process can be considered as being a first step toward Intralogistics 4.0 (Zeller et al. 2018).

In a detailed examination of the Intralogistics 4.0 maturity levels of the cases, we found that the interview cases that we assigned to the five maturity levels can be categorized into three workplace types as shown in Table 5.

As the answers of the interviewees from these three workplace types were mostly homogenous with only slight individual differences and the type and extent of technology usage was comparable, we ground the analysis of the cases on the three workplace types.

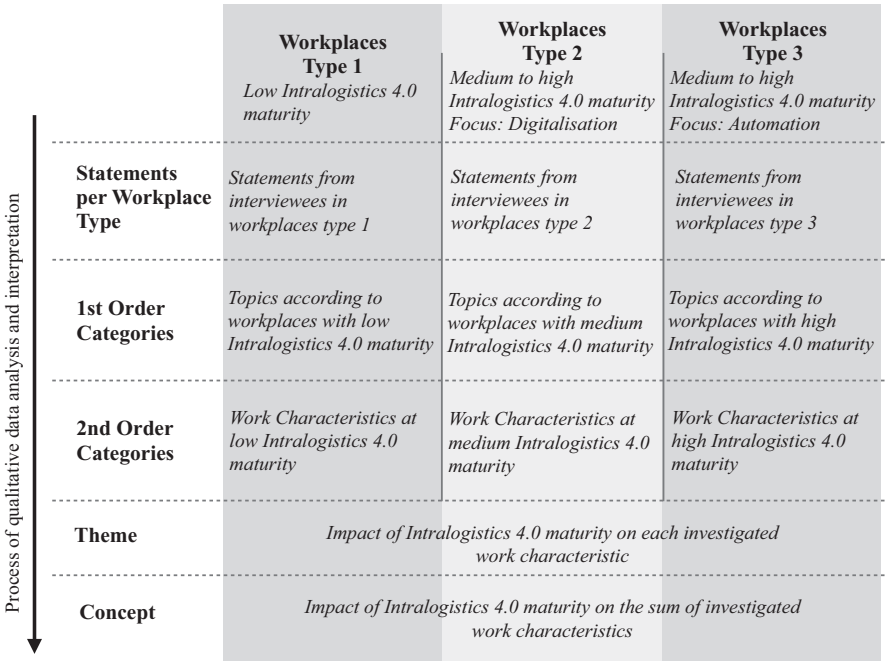

FIGURE 3 Steps of qualitative data analysis and interpretation

TABLE 5 Cases' Intralogistics 4.0 maturity

	Workplaces Type 1	Workplaces Type 2	Workplaces 3
Intralogistics 4.0 maturity	low	medium to high	medium to high
Use of digital technology	low	medium to high	medium to high
Use of automation technology	low	low to medium	medium to high
Typical technology usage	paper-based pick lists, hand pallet trucks	pick-by-voice, warehouse management systems, conveyor belts	automated storage and retrieval systems (AS/RS), warehouse management systems
Cases	4.1, 4.2, 6.1, 6.2	1.1, 1.2, 2.1, 2.2, 5.1, 5.2, 6.2, 7.2	3.1, 3.2, 7.1, 7.2

RESULTS

The interviews demonstrated significant differences in the work characteristics of the intralogistics workplaces. The main descriptive interview results consolidated in the second-order categories of the analysis are presented in Tables 6–10; in addition, exemplary citations are provided in quotations.

As can be seen, the task characteristics varied significantly between the three workplace types identified. A high Intralogistics 4.0 maturity with a widespread use of automation technology negatively impacted the task characteristics. This was mainly caused by the high process rigor and limitation of tasks for the employees who, for instance, perceived themselves as "part of a machine." Instead, high Intralogistics 4.0 maturity levels combined with a low degree of automation have only minor impacts on the assessment of task characteristics; however, the intralogistics process was impacted by the maturity level. This indicates that the change in the process kept the personal outcomes comparable. For instance, the task identity was perceived as high in workplaces with lower Intralogistics 4.0 maturity because the employees had to perform several tasks, coordinate themselves, and support their colleagues whenever necessary, thus gaining an impression of every task performed. In workplaces with high Intralogistics 4.0 maturity but a low degree of automation, processes were standardized, and the division of labor initially limited the range of tasks; however, additional tasks were performed owing to faster processes. Therefore, the range of tasks remained comparable, but the cause was different.

The knowledge characteristics also varied between the workplace types identified. In workplaces with a high

TABLE 6 Descriptive results of the interviews on task characteristics

Characteristics	Jobs with low Intralogistics 4.0 maturity and no automation (Workplace type 1)	Jobs with medium or high Intralogistics 4.0 maturity and low degree of automation (Workplace type 2)	Jobs with medium or high Intralogistics 4.0 maturity and high degree of automation (Workplace type 3)
Task characteristics			
Autonomy	perceived as not high but important; decision-making autonomy mostly in enlarged elements; work scheduling autonomy higher than in other workplaces, for example, owing to self-organization of work; work scheduling autonomy and handling of different enriched and enlarged tasks perceived as demanding; no autonomy in work methods;	perceived as not high but important; decision making and scheduling autonomy mostly reduced to enriched and enlarged elements, but also not high; within the main process, work scheduling autonomy perceived as reduced owing to, for example, put-to-light or pick-by-voice systems; no autonomy in work methods;	perceived as very low with medium importance; decision making and scheduling autonomy not provided even in fault situations owing to fixed and prepared pipeline of work tasks and complex changes of the order and correction procedures; no autonomy in work methods;
Variety	perceived as repetitive but not monotonous; opportunity of enlargement of tasks positively accepted and perceived on a medium level, for example, by supporting colleagues;	perceived as repetitive but not monotonous; opportunity of enlargement and enrichment of tasks positively accepted and perceived as high, for example, data management or quality checks	perceived no task variety; no actions even in fault situations allowed; reduction of order picking task to the picking procedure; "Good work is high, frequent work"; “The aim of my work is to pick as many items as possible”;
Significance	perceived mid to high importance of the job driven by holistic process understanding; impact on customer and company emphasized beside personal consequences;	perceived mid to high importance of the job driven by holistic process understanding; impact on customer and company emphasized beside personal consequences;	perceived low importance of the job; reduction of significance on a personal level; not the process but the worktime perceived as the end of a work process;
Identity	perceived complete and defined task; division of labor with less strict distinction; support of accompanying tasks and more holistic view on work;	perceived complete and defined task; work enlargement and enrichment enabled holistic view on work task and interdependencies;	very limited work task, perceived as very monotonous; “Actually nowadays everything is so automated that the human is nothing else than a part of a machine”;
Feedback	neither administrative nor working tasks perceived as delivering feedback from the job; feedback emphasized as being important but missing; feedback only received in failure events involving the customer;	administrative and manual tasks perceived as delivering only little feedback from the job; feedback emphasized as being important but rare, at best, for example, the calculated quantities fit exactly; most feedback received in failure events involving the customer;	tasks not perceived as delivering feedback from the job; checks of correct task performance used even in failure events; limited personal feedback; “If there is a fail and you do not know where it happened, they tell you about it, but also that you do not have to think about it”

maturity and a widespread use of automation technology, the interviewees were “performers” of standard processes, where every necessary information was provided. In case a process disturbance occurred, the task was not solved by the interviewees but by their supervisors, thus limiting the required knowledge to a minimum. In comparison, workplaces with a high Intralogistics 4.0 maturity but low degree of automation have broader knowledge needs. In most cases, the process was less standardized and had lower rigor compared to workplaces with a high degree of automation and thus, higher knowledge levels were required; however, the interviewees were more adequately supported by the technologies as compared to workplaces with low maturity. Although the knowledge needs changed, they did not decrease because the product and process knowledge had to be replaced by knowledge

TABLE 7 Descriptive results of the interviews on knowledge characteristics

Characteristics	Jobs with low Intralogistics 4.0 maturity and no automation (Workplace type 1)	Jobs with medium or high Intralogistics 4.0 maturity and low degree of automation (Workplace type 2)	Jobs with medium or high Intralogistics 4.0 maturity and high degree of automation (Workplace type 3)
Knowledge Characteristics			
Complexity	perceived low to medium complexity; additional information about work items (e.g., products and components) emphasized as necessary; complexity added by enriched and enlarged task organization, not by the task itself; "Organization, that is of course also a big part"	perceived low to medium complexity; information about the systems seen as necessary; usefulness of technologies individually perceived diverse; complexity mainly added by enriched and enlarged tasks that were more complex compared to other tasks, for example, order picking; higher demand in administrative tasks	complexity not mentioned in the interviews; "Cognitive demands are very low, because you have your monotonous movement the whole time"
Information Processing	perceived as important; a lot of information had to be processed; tasks perceived as a permanent data exchange and check; perceived medium to high cognitive demands because of repetitive tasks but necessary cautiousness	perceived as important; a lot of information had to be processed especially for enriched and enlarged tasks; tasks perceived as a permanent but more intuitive data exchange; processing and often checked by, for example, scans; "In earlier times, we worked with a list with all the items. Tick everything, pack everything, manually. The new system is a big advantage"; perceived medium to low cognitive demands owing to necessary caution but demanding interaction with, for example, pick-by-voice technology	perceived as easy and not very important; permanent checks of correct information processing; only one task at a time and intuitive information provision; perceived very low cognitive demand owing to fault resistance of the system and permanent quality checks
Problem Solving	perceived low need for problem solving within the task; coordination of different tasks sometimes addressed; coordination could be demanding	perceived medium to low need for problem solving; need for flexibility addressed; "If something is not as planned, you have to be flexible"	perceived no need for problem solving; in case of fault events, especially with the AS/RS system, only supervisors able to solve problems; "In case of a failure and you do not have someone who is able to solve it, it is very hard"
Skill Variety	skill variety seen as low; especially being able to pay attention over a long period of time, spatial imagination, calculation and equipment-usage skills named	perceived medium skill variety concerning enlarged and enriched tasks (e.g., IT skills or skills to operate machines that support the worker)	no skill variety seen as necessary; the automation systems and IT systems provide all necessary information and check the correctness; work much more standardized because of automation systems
Specialization	only a slight specialization seen as an advantage (e.g., knowledge regarding product characteristics)	perceived low skill necessity owing to system support, although knowledge about products, support systems and processes is advantageous	no specialization seen as necessary; the automation systems and IT systems provide all necessary information and check the correctness; work much more standardized because of automation systems

TABLE 8 Descriptive results of the interviews on social characteristics

Characteristics	Jobs with low Intralogistics 4.0 maturity and no automation (Workplace type 1)	Jobs with medium or high Intralogistics 4.0 maturity and low degree of automation (Workplace type 2)	Jobs with medium or high Intralogistics 4.0 maturity and high degree of automation (Workplace type 3)
Social Characteristics			
Social Support	perceived medium to high social support, for example, by helping new colleagues or with activities under strict deadlines; teamwork-enabled social interaction during work	perceived medium social support, for example, with activities under temporal restrictions or helping new colleagues; pick-by-*-systems sometimes hindered social interaction during work; "With the pick-by-voice systems, you cannot talk to your colleagues here"	perceived low importance of social support; in failure events of the technology, supervisor support is required; mainly isolated work without any interaction; "You work on your own and independently"
Interdependence	no interdependence with prior processes perceived; interdependence with subsequent process steps perceived as medium to high; importance for performing high-qualitative work;	low interdependence with prior processes perceived; interdependence with subsequent process steps perceived as high; importance for performing high-quality work	no interdependence with prior processes perceived; analogue to task significance, interdependence with subsequent process steps perceived as low to medium
Interaction outside Organization	no interaction outside the organization mentioned, except for truck drivers from service providers;	low interaction outside the organization mentioned, except for truck drivers from service providers; in enriched and enlarged tasks also further interactions; higher interaction outside organization in administrative tasks	no interaction outside the organization mentioned, except for truck drivers from service providers
Feedback from Others	little feedback received from others; most feedback from supervisors only in case an error occurred	little feedback received from others; most feedback from supervisors only in case an error occurred	no feedback received from others; most feedback from supervisors only in case an error occurred

needed for handling the technologies. Moreover, the work characteristics exhibited a small positive change but were not negatively affected.

The social characteristics were slightly affected by the technologies applied. Although workplaces with a high Intralogistics 4.0 maturity and a widespread use of automation technologies hindered social interaction in certain ways owing to the workplace design, many social characteristics were not affected by the maturity level. One reason for that could be that these social characteristics were relatively low in all Intralogistics 4.0 maturity levels. In the few cases where social characteristics were impacted, for example, in workplaces with a high Intralogistics 4.0 maturity but with low automation technology, a sensory impairment was perceived because of the pick-by-voice-systems. Additionally, social support decreased with higher degrees of automation in the process because the work was performed more isolated.

Concerning the impact of the Intralogistics 4.0 maturity level on context characteristics, two outcomes can be identified. Workplaces with high maturity and a widespread use of automation technology exhibit great gains for ergonomics and physical demands as well as equipment usage and working conditions. Workplaces with high Intralogistics 4.0 maturity and without automation technology only improve working conditions and equipment usage but have limited effects on physical demands and ergonomics.

The interviewees did not expect any further influence of Intralogistics 4.0 on their own workplaces, either because they were already relatively Intralogistics 4.0 mature or because they were not, and the employees did not expect any change to that status. As many differences were found between manually driven and Intralogistics 4.0 mature workplaces, these expectations might seem paradoxical. As experts for their jobs, interviewees considered other jobs (e.g., truck driving) as more likely to be transformed. One possible reason can be the missing knowledge regarding possible IT influences as compared to, for example, robots that were named more often. For instance, order pickers assessed their tasks as too complex for robots; however, they did not address the influences of

TABLE 9 Descriptive results of the interviews on contextual characteristics

Characteristics	Jobs with low Intralogistics 4.0 maturity and no automation (Workplace type 1)	Jobs with medium or high Intralogistics 4.0 maturity and low degree of automation (Workplace type 2)	Jobs with medium or high Intralogistics 4.0 maturity and high degree of automation (Workplace type 3)
Contextual characteristics			
Ergonomics	perceived as ergonomically not optimal owing to suboptimal product offering (especially long walking distances)	perceived as ergonomically not optimal owing to suboptimal product offering (high-reaching, heavy weights, long distances)	perceived as ergonomically good workplaces; support of the worker
Physical Demands	most often perceived as physically high demanding owing to heavy goods and suboptimal product offering	perceived as physically medium demanding owing to heavy goods; "We always have the right equipment, so we do not have to destroy ourselves"	perceived as physically low demanding as goods and packages were designed with limited weights; no strenuous movements necessary at the workplace
Work Conditions	perceived as needing improvements, for instance, dusty environment or cold environment in the winter	perceived as generally good; little need for improvement perceived	perceived as nearly optimal; no need for improvement perceived
Equipment Use	perceived as not very important but helpful, especially for handling heavy material; "The equipment we have is very helpful especially in handling heavy goods"	perceived as medium important and helpful, as in handling heavy goods; IT equipment helpful for information tasks; necessary knowledge about how to handle the system best perceived as interesting	perceived as helpful to ease the physical work, especially the automation system, which is supported by the IT systems, but also as a simplifier of work, leading to boring and monotonous workplaces; "Actually I don't like working with the automated system. [...] It is no challenge. And then, it is getting boring"

TABLE 10 Descriptive results of the interviews on individual expectations

Characteristics	Jobs with low Intralogistics 4.0 maturity and no automation (Workplace type 1)	Jobs with medium or high Intralogistics 4.0 maturity and low degree of automation (Workplace type 2)	Jobs with medium or high Intralogistics 4.0 maturity and high degree of automation (Workplace type 3)
Individual Expectations			
Future Logistics 4.0 Developments	only minor changes in terms of digital transformation expected in the middle range as tasks are too complex; resistance by older employees expected; hope to ease manual tasks	no future trend for digital transformation expected owing to already supported processes; hope to ease manual tasks; possibility of support business processes is a current challenge; data security perceived as a future challenge	no future trend for digital transformation expected owing to already supported processes; fear of complete shutdowns; loss of individuality

IT in depth. This underlines the difference between automation and digital technologies for manual workplaces, where automation technology seems to be dominant. On the worker level, most of the hypothesized influences were negatively perceived for their own workplaces and related tasks (e.g., fear of losing their jobs), although positive impacts, such as ergonomic improvements, were also found.

DISCUSSION

The results described above hint at the important implications technology application has on work characteristics. The remaining *RQs* 2–4 are answered in the following.

To further answer *RQ* 2—what are the influences of digital technologies as compared to automation technologies

on work characteristics and what are the driving and inhibiting mechanisms behind this—the following results can be derived. Our findings show that the impacts of the Intralogistics 4.0 maturity level on work characteristics depend on the technology applied and the importance of the technology for the task that has to be performed.

Overall, digitalization can be seen both as a multiplier and diversifier of manual work tasks in intralogistics. Digitalization standardizes, speeds up, or replaces work; therefore, work could be enriched or enlarged. For work characteristics that are only slightly influenced by digitalization, such as physical demands or ergonomics, the perception of analogue and digitalized workplaces was similar. In contrast, high degrees of automation simplify manual work tasks in intralogistics. Popular systems, such as AS/RSs, reduce the number of work tasks remaining for the workers instead of supporting and cooperating with them. Therefore, tasks were often perceived as highly standardized, redundant, and monotonous in such workplaces, and they were not accompanied by job enlargement in most cases. The resulting limitation of work tasks led to a deterioration of several work characteristics such as task variety or task identity.

To answer *RQ* 2, also the mechanisms between the implementation of a technology and the impact on work characteristics are relevant. This means that the implementation of a certain technology does not inhibit or improve a work characteristic directly but may do it indirectly due to certain ways of usage, for example, the implementation of separated pick cells in an AS/RS that inhibit social interaction. To understand these impacts of automation and digital technologies on the work characteristics in more depth, the underlying mechanisms identified in the interviews are presented in Figures 4 and 5. Overall, nine different mechanisms with a negative impact and seven with a positive one were identified.

The mechanisms identified above can influence the relation between changes in work and work characteristic in complex ways. As exemplarily shown in Figure 6, a certain change of the process can lead to more standardization, which could impact the work characteristic autonomy directly and other characteristics indirectly with positive or negative impacts on the work characteristics. Hence, the identified mechanisms serve as indicators for the actual process design that was comparable within the Intralogistics 4.0 maturity levels.

In summary, we found that all four work characteristics categories were influenced by the Intralogistics 4.0 maturity with different mechanisms, although the cases did not achieve the highest Intralogistics 4.0 maturity ratings.

These analyses further enable us to answer *RQ* 3—which role does the Intralogistics 4.0 maturity play in job satisfaction. Considering the impacts of the Intralogistics

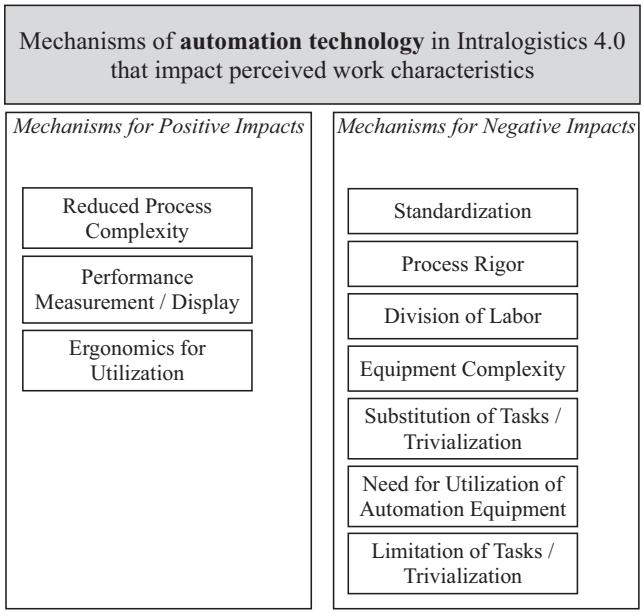

FIGURE 4 Mechanisms of automation technology on work characteristics

4.0 maturity on work characteristics relevant for job satisfaction, the overall effect can be both positive and negative, depending on the exact system design of the workplace and the preferences of the employees. However, for the investigated cases, we found that medium to high levels of Intralogistics 4.0 maturity without or with low degrees of automation improve job satisfaction because the implemented technologies support the workers, leading to enlarged or enriched work, for example, with higher degrees of variety and identity along with lower loads as compared to manual workplaces. This seems plausible because manual work tasks can be impacted, but not fully substituted by digital technologies. In contrast to this, high degrees of automation can have a strong impact on manual work tasks leading to a significant reduction of work characteristics relevant for job satisfaction in most cases. However, this is not unavoidable as, for instance, adaptive automation technologies may lead to different effects that were, however, not observed in this study.

Evaluating our answers to *RQ* 2 and *RQ* 3 in the context of the state of knowledge (see literature summarized in the Appendix 1), the following findings can be summarized:

1. We confirmed earlier research that had shown that automation simplifies the work and reduces the requirements, for example, in terms of knowledge and capabilities (de Witte & Steijn, 2000).
2. In accordance with the literature, we found that process rigidity increased with technology usage, especially when applying automation technology, and that it negatively impacted the work characteristics; however,

increasing process complexity was not found to play a major role in the cases compared to the findings of, for example, Bala (2013). On the contrary, depending on the Intralogistics 4.0 maturity level, decreasing complexity was identified to have an influence on work characteristics. A reason for this could be the different composition of the interviewees in the earlier studies compared to ours and the scope of work performed that was, for example, not based on complex IT systems in most cases included in our study. In addition, the effects of digital and automation technologies on autonomy, skill variety, and feedback were not determined; they were diverse depending on the applied technology (Waschull et al. 2020). This clearly indicates that a cross-technological consideration is necessary to determine the impacts of Intralogistics 4.0 on work characteristics to design satisfactory workplaces.

3. Digitalization and automation transform work characteristics, but automation technology was found to have a much stronger impact on work characteristics than digital technologies for the mostly manual tasks in intralogistics. In contrast to the findings on IT systems and the expectations in conceptual studies included in the systematic literature review, processes became less complex or remained comparably complex in high Intralogistics 4.0 maturity levels owing to the standardization of processes and knowledge provisions at the shopfloor (Waschull et al. 2020). Hence, knowledge needs and skill variety changed (but remained on the same level) or decreased depending on the technological focus of the transformation. In accordance with the literature, we expect this difference to also depend on the skill level and job level of employees (de Witte & Steijn, 2000).
4. Improvements of social characteristics were not observed in this study, which is in accordance with the findings in the literature for blue-collar workers (Castellacci & Viñas-Bardolet, 2019). The most important difference between social characteristics for different Intralogistics 4.0 maturity levels can be observed according to social support, which was low for high Intralogistics 4.0 maturity levels with a widespread use of automation technology. In these cases, processes and information provision are standardized to an extent that no social support or interaction is necessary, and workplaces do not provide opportunities for this kind of interaction—in short: social was substituted by technological support.
5. Intralogistics 4.0 can positively impact context characteristics, and workplaces with a high Intralogistics 4.0 maturity and a widespread use of automation technologies have an even higher potential to optimize these characteristics as compared to workplaces with a focus on digitalization. This might be a consequence of the necessary and predefined structure of the workplaces' automation technology needs and higher demands automation technologies have on the environment the workers benefit from.
6. Several mechanisms that reach beyond the findings of the literature review were identified and conceptually

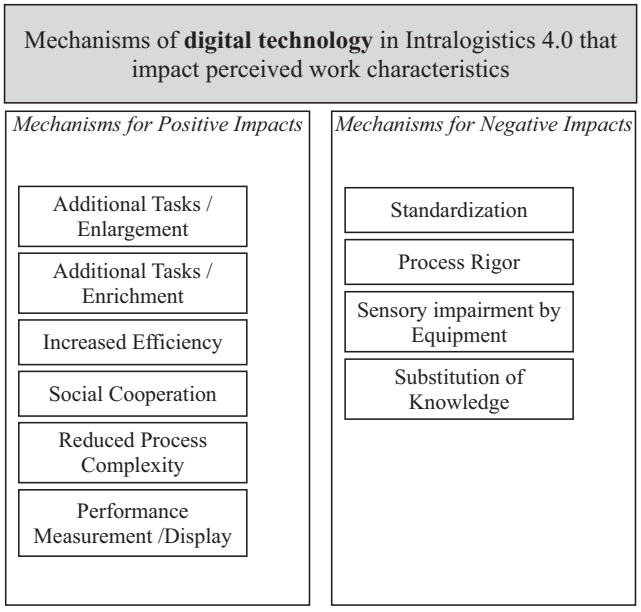

FIGURE 5 Mechanisms of digital technology on work characteristics

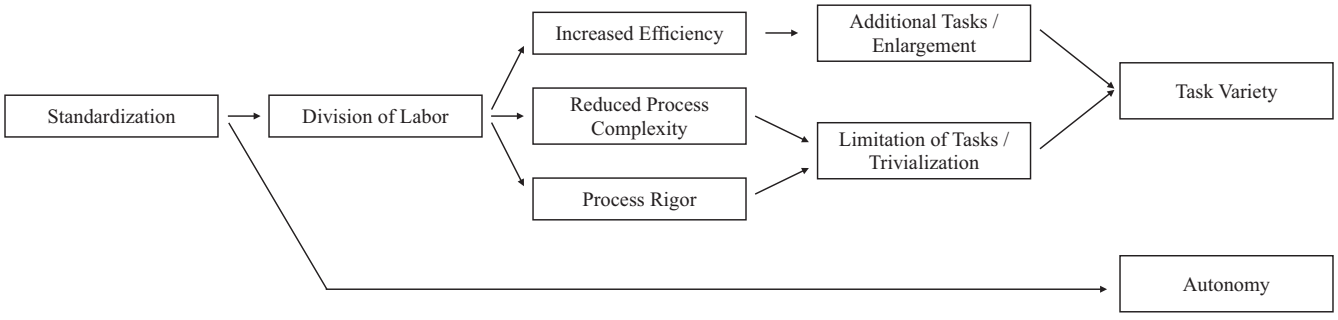

FIGURE 6 Process chain of possible mechanisms impacts

expected outcomes were empirically verified. For example, process complexity and rigidity were already discussed in the literature, but sensory impairment or performance measurement and display were not addressed in the literature on work characteristics relevant for job satisfaction. Overall, the current study identified several aspects in the literature that need to be discussed and further differentiated to fit the complexity of current developments pertaining to Intralogistics 4.0 systems.

Lastly, *RQ* 4 was addressed in this context—how practitioners can anticipate the development toward Intralogistics 4.0 in the design of future workplaces in intralogistics. Considering the changes of work characteristics in Intralogistics 4.0, some propositions for practitioners can be derived. These insights can be used by practitioners to develop technology strategies, and they can inspire the organization of work and the design of workplaces to improve work characteristics. Figure 7 exemplarily shows how the implementation of technology can positively impact a certain work characteristic: The technology (left column) can trigger the assigned exemplary mechanism in the middle column and finally influence the respective work characteristic in the right column. For example, IT-based planning support for generating alternatives can help employees, such as order pickers, to choose from a number of pick-plans according to personal preferences, for example, "heavy goods first", "small orders first", or similar task scenarios. Although the actual pick sequences may be fixed for these pick-plans, such a decision returns some autonomy to the employees. We termed such mechanisms as "informed decision competency" (see Figure 7), which was not identified during the interviews. Another example could be the implementation of gamification modules that provide feedback from the job using measures for displaying relevant process information to the employees.

Among all these examples, the inclusion of employees at the beginning of a technology implementation is important for practitioners to avoid an innovation pitfall (Neumann et al. 2021). As outlined above, the overall effect of a certain technology on the work characteristics might not be initially predictable due to overlapping effect chains. Actively designing these effect chains might require deviating from standard solutions, introducing new forms of organization, and thinking out-of-the-box. Therefore, considering the employees' perspectives provides stronger evidence to the presumed relations. Additionally, a path dependency was detected in both the development of Intralogistics 4.0 and the subsequent reactions of the employees toward it. As outlined when discussing the future expectations of the interviewees, the employees' perceptions, anxieties, and hopes were diverse and depended on past experiences.

CONCLUSION

This article provides a qualitative approach to deepen our understanding of the impacts of Intralogistics 4.0 on work characteristics and job satisfaction focusing on intralogistics workplaces.

Contribution to theory

To the best of the authors' knowledge, the current study is the first to investigate the influence of the Intralogistics 4.0 maturity level on work characteristics of intralogistics employees, aiming to empirically deduce the impacts of digitalization and automation on job satisfaction. We expand the state of research by empirically examining how automation and digital technologies of real work systems affect the work characteristics of manual intralogistics workplaces, and which mechanisms—that serve as intermediaries between implemented technologies and their effects on work characteristics by means of, for example, process changes—are essential. Three types of workplaces were found within the cases: workplaces with low Intralogistics 4.0 maturity, workplaces with medium to high Intralogistics 4.0 maturity but without or only a limited degree of automation, and workplaces with medium to high Intralogistics 4.0 maturity and a widespread use of automation technology. Evidently, these different technology setups have different influences on the work, mainly in manual workplaces. The different work characteristics evaluated are related to the Intralogistics 4.0 maturity type (*RQ* 1) and technologies applied (*RQ2*). The results highlighted that a higher Intralogistics 4.0 maturity does not necessarily contribute toward job satisfaction; instead, it depends on the technology applied and mechanisms that are triggered (*RQ* 2). These factors impact job satisfaction, but not in a linear or unidirectional way (*RQ* 3). Although the impacts and mechanisms are diverse, propositions could be derived for practitioners that can lead to an improved Intralogistics 4.0 implementation (*RQ* 4).

Taking a wider perspective on these results, this study also contributes to the resource-based view of the firm. As proposed by Neumann and Dul (2010) humans can be considered as a resource in an operation system that, in turn, can have an influence on the sustained competitive advantage of the firm. If the impact of a system change, for example, through the introduction of Intralogistics 4.0 technologies, on employees is not carefully considered,

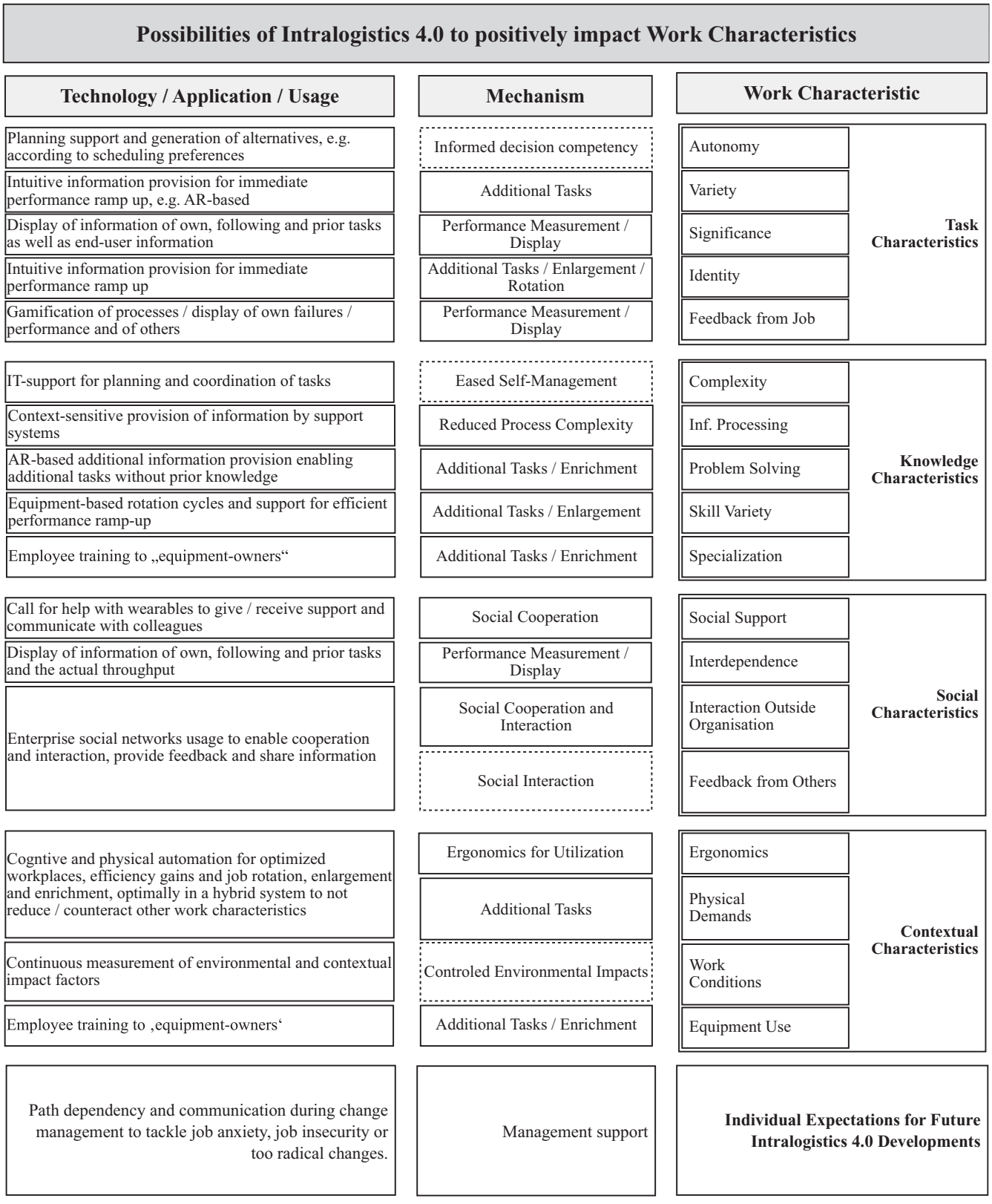

FIGURE 7 Possibilities of Intralogistics 4.0 to improve work characteristics

the risk of systems that fall short of their expectations—and that create so-called phantom profits—increases (Neumann & Dul, 2010; Sgarbossa et al. 2020). This study shows that technology-induced changes of the work system also impact work characteristics of employees in Intralogistics 4.0. Hence, it is necessary for companies to pay attention to these effects on work characteristics to prevent phantom profits and develop employees as a key resource for a successful development.

Implications for research and practice

For researchers from different disciplines, this study builds an important baseline: Researchers are provided with a qualitative analysis that examined the impacts of both automation and digital technologies and their effects on work characteristics. Additionally, the study applied an individual-level investigation across a diverse range of impact factors like workplaces and companies. Thus, this study contributed toward the existing knowledge for future studies.

For managers, this study offers initial insights for work design toward the developments of Intralogistics 4.0, especially in cases where new technologies are implemented and the work system is redefined; two main insights were obtained: (1) The study supports the development of workplace designs that are beneficial for the company and the workers, thus enabling an enriched and productive work system, and (2) the decision for or against a certain technology could be influenced, because the implemented technologies might determine the work processes and have different influences on work design.

On a more general level, the role of human factors is very important in logistics and operations management and several studies highlighted the joint objective of human factors and system performance objectives (Neumann et al. 2021). Hence, paying attention to the effects of the change of the (sociotechnical) operations system on employees also contributes to system performance. As there is a potential impact of introducing Intralogistics 4.0 on employees' work demands and job satisfaction, this study gives insights into which aspects should be considered carefully during the implementation phase and how the changes can impact employees' work characteristics. As outlined by Sgarbossa et al. (2020), "it would be important to consider and predict human effects of adopting a new tool/instrument and subsequently, the impact of HF on system performance and not only on investment cost." In this regard, this study contributes a first step as we evaluated relevant changes of work characteristics in a changing technological environment in intralogistics. However, this study did not consider the performance impacts, which could be addressed in a follow-up study.

Limitations

This work has limitations. First, the study was conducted based on the evaluation of work characteristics. However, there are alternative models that could be assessed as relevant for job satisfaction, which might have led to a different structure of the study. Second, the study only referred to intralogistics workers, which might limit the explanatory power beyond the borders of intralogistics tasks. Having prior different work characteristics might also change the perception of the work characteristics in higher levels of Intralogistics 4.0 maturity and different technologies might have other impacts. Additionally, the number of cases for each workplace type was limited, although saturation occurred during the interviews. Nevertheless, a more detailed analysis that could be grounded on the results of this study could further investigate the effects of the digital transformation on work characteristics and the mechanisms between them. Third, although the cases had different characteristics in terms of size, sector, and Intralogistics 4.0 maturity, some warehouse systems and organizations are very rare or just emerging. A further study could investigate new technology implementations such as hybrid order picking systems, where robots share the shopfloor with order pickers. This could lead to promising insights given that recently introduced technologies, such as augmented reality or collaborative robots, were not used in the interviewees' workplaces, and highest levels of Intralogistics 4.0 maturity were not achieved yet, which is a limiting factor of this work. The results obtained in this study could consequently change as new and more adaptive technologies enter intralogistics workplaces. The Intralogistics 4.0 maturity model used in this study could also be revised to exclude the lowest levels of Intralogistics 4.0 maturity from the Intralogistics 4.0 maturity concept altogether. Additionally, there might be further impacts and mechanisms that were not identified within the interviews but that lead to work characteristic changes. Fourth, a statistical analysis of the results was not possible owing to the methodology used, and the data interpretation was grounded on subjective representations instead of ratings, as in a questionnaire. In this context, future research could follow up on the insights obtained in this study and try to quantify the impacts of technologies on the identified mechanisms as well as on job satisfaction or examine this in various workplaces such as assembly lines or road transport. Moreover, future research could

focus on related topics, for example, by incorporating the productivity outcomes of such workplaces in a case study.

Overall, this study showed some major effects of the digital transformation on manual workplaces, particularly in intralogistics. Our results encourage more research on incorporating human factors in the design of Industry 4.0. We argue that both managers and researchers are responsible for establishing workplaces that fit human requirements and needs. The findings of this study could be used for better work design and to improve the job satisfaction of intralogistics workers, which will contribute toward successfully managing the digital transformation of intralogistics in practice.

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APPENDIX 1

Summary of key findings of the systematic literature review

#	Article	Methodology	Core findings related to work characteristics/ job satisfaction
1	Bailey (2000)	Survey	External factors, such as conflicts with supervisors, are predictors of work-group productivity, and internal factors, such as internal conflicts, can more accurately predict job satisfaction than factors such as autonomy, which has a low predictive value
2	Bala (2013)	Longitudinal Study	The implementation of an IT system (supply chain management system) has an effect on perceived process rigidity and process complexity, which has a negative impact on job outcomes such as satisfaction
3	Bala and Venkatesh (2013)	Longitudinal Study	The implementation of an IT system (ERP system) and the perceived technology characteristics impact perceived process complexity, rigidity, and radicalness that have an impact on perceived job demands, job control, and job satisfaction
4	Bala and Venkatesh (2016)	Longitudinal Study	The employees can perceive an IT system implementation as an opportunity or a threat; the resulting technology adaption behaviors have an impact on their job satisfaction
5	Brah and Ying Lim (2006)	Survey	High-technology logistics firms perform better than low-technology logistics firms, and it is hypothesized that technology usage has the potential to enrich jobs and that it can positively drive job satisfaction
6	Carlson et al. (2017)	Survey	Turnover intentions are impacted by job satisfaction and organizational commitment that vary upon influences of technology-based job autonomy, overload, and monitoring on job engagement and tension
7	Castellacci and Viñas-Bardolet (2019)	Analysis of Survey Data	The use of the Internet positively affects job satisfaction by improving factors related to social interactions and autonomy. Less positive effects are observed for blue-collar workers
8	de Witte and Steijn (2000)	Analysis of Survey Data	Jobs with a higher degree of automation have different effects on blue-collar, white-collar, and professional employees; for blue-collar employees, a deskilling due to internal differentiation can be observed, which impacts job satisfaction but not because of decreasing autonomy or complexity
9	Elias et al. (2012)	Analysis of Survey Data	Age moderates the attitude toward technology and has effects on intrinsic and extrinsic motivation. The moderating effect of age on job satisfaction is less pronounced
10	Hannola et al. (2018)	Conceptual	There are four kinds of digitally facilitated knowledge management processes for production workers that contribute toward job satisfaction and efficiency
11	Korunka and Vitouch (1999)	Longitudinal Study	The effects of an IT system implementation on stress and satisfaction mainly depend on the context of change and the implementation management
12	Kwahk and Lee (2008)	Survey	The behavioral intention of using an IT system (ERP system) is indirectly impacted by the readiness for change, which is influenced by personal factors such as organizational commitment

#	Article	Methodology	Core findings related to work characteristics/ job satisfaction
13	Mariani et al. (2013)	Survey	Providing training opportunities impacts the employees' acceptance of an IT system as well as job satisfaction
14	Martin and Omrani (2014)	Analysis of Survey Data	The use of the Internet affects job attitudes positively and thus increases job satisfaction, which is impacted by changes in accessing knowledge and social interaction
15	Mitchell et al. (2012)	Survey	Organizational support has a positive influence on employees' attitudes and behavioral reactions toward new IT systems
16	Morris and Venkatesh (2010)	Longitudinal Study	The implementation of an IT system (ERP system) moderates the effects of autonomy, skill variety, and feedback on job satisfaction but does not moderate the effects of task significance and task identity on job satisfaction
17	Navimipour et al. (2018)	Survey	The organizational performance is influenced by IT-related factors such as ease of use; further, it is impacted by organizational culture including job characteristics, and employees' satisfaction
18	Ötting and Maier (2018)	Vignette Study	The employees' behaviors and attitudes, including job satisfaction, are impacted by procedural justice in work-related decisions, independently of the decision agent (human or computer)
19	Salanova et al. (2004)	Survey	The type of an IT system implementation has a significant impact on the employees' cognitive well-being including job satisfaction
20	Schwarzmüller et al. (2018)	Expert Survey	Work design and leadership are changed through digitalization, for example, by setting higher job demands for employees, increased technologization, and changes of communication and collaboration
21	Seppälä (2004)	Interviews and Survey	The role of white-collar employees in production industry changes, also based on advanced IT systems, leading to changed job characteristics such as variety and autonomy
22	Sykes (2015)	Longitudinal Study	During the implementation of an IT system (ERP system), traditional support structures and peer-advice impact employees' perceived system satisfaction, job stress, and job satisfaction
23	Venkatesh et al. (2010)	Longitudinal Study and Interviews	The implementation of IT systems and communication technology systems enriches jobs and improves job characteristics; however, the effects on job satisfaction depend on contextual forces that are also related to the characteristics of industrial sectors in India and possibly other developing countries
24	Waschull et al. (2020)	Conceptual	Depending on the task to be performed, the application of CPSs can create new human tasks or substitute them, resulting in enriched, simplified, and substituted jobs; this subsequently changes the job characteristics such as autonomy, complexity, and skill requirements